# CHONDRULE PRECURSOR AGGREGATES IN UOC'S: IMPLICATIONS FOR THE CHONDRULE FORMING PROCESS

G. E. Lofgren, SN-4, NASA Johnson Space Center, Houston, TX 77058.

Chondrule precursors in the form of fragmental aggregates have been found in unequilibrated ordinary chondrites, UOC's [1, 2]. These aggregates not only attest to extensive recycling as part of chondrule formation, but also suggest a process to produce chondrule compositional variation. The fragmental precursors are comprised of 6 major components including chondrules and fragments therefrom, Fe-metal and sulfide minerals, and chondrite matrix and rim material. The chondrule compositions are a function of random mixtures of these components in a manner similar to that described by Alexander [3]. These findings suggest a solar nebula with a long and complicated history with many heating events and sufficient movement and density of particles to allow numerous collisions and comminution of chondrules and the subsequent aggregation of the generated debris followed by reheating and formation of new chondrules in repetitive cycles.

**Descriptions:** In an accompanying abstract [2] the most important particle observed in the UOC's is the **fragmental aggregate**. This aggregate represents a basic process in the nebula. It formed by accidental collisions of 6 major components of nebular debris. This debris is comprised mostly of chondrules and chondrule fragments, chondrules further comminuted to individual olivine and pyroxene crystals, chondrule mesostasis fragments, Fe-metal and sulfide minerals, coarse- and fine-grained clastic aggregates, and chondritic matrix and rim material. The fragmental aggregate formed in the nebula and may or may not be enclosed in a clastic, metal/sulfide, or a nebular rim. All fragments in the aggregate did not necessarily come together at the same time, consequently some of the fragments or groups of fragments may have acquired rim material before final aggregation.

Special case aggregates that are often part of fragmental aggregates, but also occur individually, contain primarily clastic debris and rarely chondrule fragments. Clastic materials most likely derive from chondrules, but some of the clastic debris could be primary condensate minerals. These particles may or may not show partial melting and may or may not contain metal or sulfide minerals. There are 2 distinct groups. **Coarse-grained, clastic aggregates** containing olivine and pyroxene generally coarser than 20 micrometers. The grain size can be uniform, but usually they are characterized by a wide range of grain size and shape. They usually exhibit some partial melting and even some euhedral crystals which most likely form as overgrowths on crystals developed upon cooling. The aggregates range from rounded to subangular becoming more rounded with increased partial melting. It is difficult to prove the nature of these aggregates. Nebular rims when present suggest their place of origin and the occasional chondrule fragment their mode of formation. **Fine-grained, clastic aggregates** appear dark in plane light mostly because they are so fine grained. They usually have an irregular outline and may be metal rich or have a metal-rich rim. Some contain abundant rounded metal grains, some have none. I suspect these are aggregates primarily comprised of typical OC rim or matrix material and finely comminuted chondrule material. Where partial melting occurs, subsequent overgrowths that develop upon cooling give some of the crystals euhedral outlines. If there is partial melting, then the metal is usually spherical. With increased partial melting, the more rounded the particle the more the metal migrates outward. The particles described by [4,5; Weisberg and Hewins] are included in this category, though some of the aggregate olivine particles of [4] may be coarser grained.

Rims are an important feature and provide much of the evidence for interpreting the history of the aggregates. Many kinds of rims have been defined and described and most are attributed to nebular processes [6-8]. Of the many kinds of rims already defined, few seem to include a simple clastic rim enclosing or partially enclosing a particle. Such rims are described by [9], but the full range of textures were not noted. I think these rims are common and an important process in the aggregation of the precursor aggregates. **Clastic rims**: Rims or partial rims comprised primarily of clastic olivine and pyroxene (angular crystals 5-20 microns), but also including Fe-metal and sulfides mostly troilite and other fine-grained rim or matrix-type debris. These rims may be partially melted and have slightly rounded to subrounded crystals or the crystals could have euhedral overgrowths and a glass or fine grained mesostasis. Some fine-grained, clastic aggregates may be slices through thick clastic rims [9]. With extensive partial melting they would become the igneous rims described by Krot and Wasson [8]. These particles with their clastic rims may be enclosed in a nebular rim comprised of fine grained chondritic matrix-type material and often Fe-metal and sulfide.

**Discussion:** A model for the crystallization of chondrules presented by Lofgren [10] is based on the melting of previously formed precursors comprised of crystalline materials. The model suggests total or extensive partial melting of these precursors to form the igneous, melt-droplet chondrules. A natural consequence of this model is that there will be less completely melted precursors produced in the same process. Based mainly on geochemical arguments, many authors have suggested that such precursors are mixtures of previously formed chondrules, chondrite matrix, and other minor materials [e.g. 3,11]. This study was based on the premise that, if the model works, nearly every particle in a relatively pristine chondrite (UOC) should be explainable as either an igneous chondrule or precursors with varying degrees of partial melting. While that ideal result has not been achieved, chondrule precursors are clearly present in the form of fragmental aggregates. These aggregates have complex histories that have been revealed by careful petrography [1,2]. The history of one such aggregate begins with the extensive fragmentation of previously formed chondrules into smaller crystals and mesostasis fragments. These fragments recombine into clastic aggregates of widely varying constitution. These aggregates and other larger chondrule fragments may or may not acquire nebular rim materials or undergo partial melting before accumulation into a new fragmental aggregate. This aggregate may form sequentially so that individual fragments have distinctly different thermal and rimming histories. As the combined fragmental aggregate reaches its final size, it may acquire a clastic rim of the same comminuted crystals found in its component fragments or entirely different material of distinct composition. This rim may partially or completely enclose the aggregate and may include Fe-metal and sulfide minerals and clasts of previously formed chondrite matrix or rimming materials. The final event recorded in some fragmental aggregates is the addition of a very fine-grained nebular rim that may or may not include Fe-metal and sulfide. These same rimming sequences can also enclose a singular clastic aggregate, a simple chondrule fragment aggregate, or any combination of the described components. All of the major possible combinations have been documented. It is easy to see that if one of the fragmental or other aggregates was totally melted and crystallized as a droplet chondrule all of the previous history is obliterated and the only remaining evidence will be the chondrule com-position; the result of whatever aggregated into that particular precursor. If aggregates form locally and quickly, they may reflect the composition of its immediate, fragmented precursor, and some surely do. But, if they form slowly and collect material from a larger part of the nebula, the possible compositional variations are much more extensive.

These findings compliment and support previous models such as the one presented most recently by Alexander [3]. He identified and analyzed possible precursor components and recombined them in a random fashion to produce the trace and minor element signatures of the known chondrule compositional range. He further suggested that chondrule mesostasis is an important player is such a model. Chondrule mesostasis has been directly observed to be a component in the aggregates.

**Conclusions:** Fragmental aggregates that appear to qualify as chondrule precursors have been identified in UOC's. They form by the random aggregation of nebular and chondrule components. Chondrule composition will vary as a function of components that happen to come together to form a particular precursor.

**References:** [1] Lofgren G. E. (1996) *MAPS* **31,** A81 [2] Russell P. and Lofgren G. E. (1997), this volume. [3] Alexander C. M. O'D (1994) *GCA* **58**, 3451-3467. [4] Weisberg M. K. and Prinz M. (1996) In *Chondrules and the Protoplanetary Disk*, R.H. Hewins, R.H. Jones, E.R.D. Scott, eds. pp. 119-127. Cambridge U. Press. [5] Hewins R. H. et al. (1996) *LPSC XXVII*, 537-38. [6] Rubin A. (1984) *GCA* **48,** 1779-1789. [7] Alexander C. et al. (1989) *EPSL* **95**, 187-207. [8] Krot A. and Wasson J. (1995) *GCA* **59,** 4951-4966. [9] Alexander C. M. O'D (1995) *GCA* **59**, 3247-3266. [10] Lofgren G. E. (1996) In *Chondrules and the Protoplanetary Disk*, R.H. Hewins, R.H. Jones, E.R.D. Scott, eds. pp. 187-196. Cambridge U. Press. [11] Grossman J. and Wasson J. (1983) In *Chondrules and Their Origins*, pp. 88-121. Lunar Planet. Inst.